Team 9 – Advanced Image Sensor Modules for Wearable Miniature Microscope

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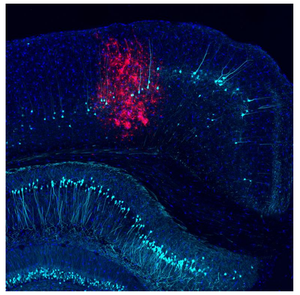
Mentors: Professor Milton Aguirre, Professor Axel Nimmerjahn

Customer Background

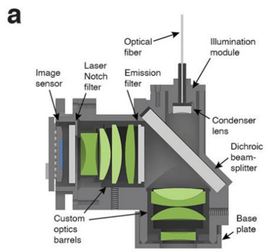


Synapses inside a spinal cord section.
Source: Salk

The **Salk Institute for Biological Studies** is one of the **world's preeminent** research institutions focused on furthering our understanding of the **life sciences**. **Professor Nimmerjahn** and his team at the **Waitt Advanced Biophotonics Center** are driving the advancement of **imaging technologies** to research the **central nervous system** (CNS) of mice for understanding **diseases** and conditions that affect humans.

Problem/Scope of Work

The Salk Institute has been working on **imaging** of the CNS of mice, developing **miniature wearable microscopes** and **imaging modules** to capture the **synapsis** inside the spinal cord in response to a stimulus. Thanks to **advancement**s in the **microscope optics**, they have been able to develop a new generation of miniature microscopes able to capture **color** with **increased field of view**. The team is tasked with **designing**, **manufacturing**, and **testing** an **image module** that utilizes an image sensor selected by a previous Capstone team to **match the capabilities** of their new development.



Third generation microscope.
Source: Salk

Requirements

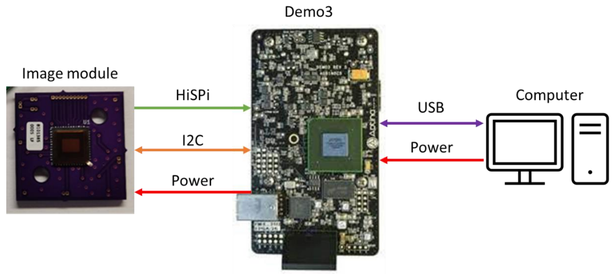
Requirement	Description of Metric	Test to Verify
FPS	Camera must output at least 45 frames per second(FPS) at target resolution	Measure FPS using imaging software (DevWareX)
Resolution	Camera must output 720p or higher resolution.	Measure resolution of camera video frames using imaging software (DevWareX)
Sensitivity	Sensor must provide 5.48 V/Lux-sec sensitivity.	Verify manufacturer specifications, test in low light conditions, and compare to image standard.
Dynamic Range	Camera must provide at least 115 dB of dynamic range.	Test in variable light conditions using imaging software (DevWareX).
Sensor Module Weight	The sensor module must not exceed 1.5 g.	Weight sensor module prior to integration using scale.
Sensor Size	Sensor must not exceed 1/3" form factor.	Measure sensor dimensions using caliper.
Sensor Color – Mono	Sensor must be capable of monochromatic images	Test in monochrome mode and compare to image standard.
Communication Distance	Maximum data communication distance must exceed 2 m.	Demonstration with data transfer cables over 2 m.

Concepts and Experimentation

The electrical system is composed of two parts: **Demo3 board** and **PCB image module**. The demo board that was provided by the client (manufactured by OnSemi) is a **FPGA** designed to interface with the AR0331 to send **video** to the **computer**. The **image module** PCB will house components needed for **power supply** and **interfacing** with the Demo3 board. This includes voltage regulators, an oscillator to provide a lock frequency to the image sensor, a level shifter to enable I2C communication between the image sensor and the Demo board, and the image sensor itself to capture what the microscope is viewing.

The mechanical system consists of the **PCB housing** which **attaches** the PCB image module to the microscope and serves as a **heatsink** to maintain the temperature of the system within manufacturers specifications. The housing is made of **aluminum** and **CNC-milled** in order maximize heat transfer rate and durability. The design utilizes **fins** for heat dissipation and ease-of-manufacturing.

PCB housing



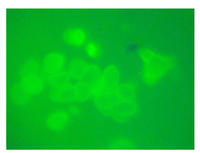
Electrical system

Testing

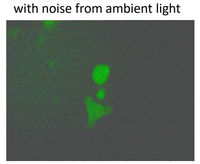
List of Tests	Description	Results
PCB Component Test	Validation of PCB Component Values	All component values correct.
Image Sensor FPS and Resolution Test	Validation of Image Sensor Specs	FPS and Resolution match requirements.
Fluorescence Pollen Focusing Test	Microscope/Image Module Integration Test	Pollen comes into proper focus.
Image Sensor Sensitivity Test	Validation of Image Sensor Specs	Sensitivity results match requirements.
Image Sensor Dynamic Range Test	Validation of Image Sensor Specs	Dynamic Range matches requirement.
Image Module Physical Test	Validation of Weight and Size	Weight and Size match requirements.
Image Module Temperature Test	Thermal Test Under Load	Temperature within threshold values

PCB housing

A surplus microscope has been used as the basis for the **test stand** for the image module. A **constant current power supply** controls the **brightness** of the **illumination LED**. The **distance** between the **sensor** and the **microscope** is adjusted by screwing it and unscrewing it with a **step size** of **125 µm**. The **sample distance** to the microscope is adjusted with the **knobs** on the side of the test stand.



Pollen image out of focus and with noise from ambient light

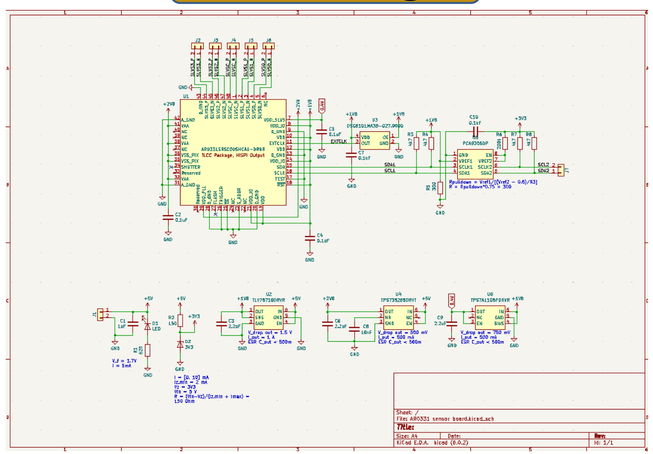


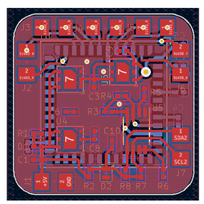
Pollen image focused with ambient light noise removed

FMEA

Item /Function	Requirements	Potential Failure Mode	Potential Effect(s) of Failure	Potential Causes(s) of Failure	Current Design Controls Prevention	Current Design Controls Detection
Image Sensor/ Component Operation	Video FPS of 45	PCB thermal performance causes sensor to limit performance to preserve image quality	Lower than 45 FPS can cause image sensor to miss crucial subject information	Components located on board producing heat compounding with sensor heat, sensor not functioning properly/incorrectly deployed	PCB designed to separate components, testing of sensor before implementation	Manufacturer temperature cuttoff to preserve components, measuring of temperature under load
	Image resolution of 720p	Thermal performance causes image degradation	Poor resolution will cause difficulties in analysis of images	Components located on board producing heat compounding with sensor heat, sensor not functioning properly/incorrectly deployed	PCB designed to separate components, testing of sensor before implimentation	Manufacturer temperature cuttoff to preserve components, measuring of temperature under load
Image Sensor/ Electrical Parameters	Durable soldered connections	Image pipeline disrupted, image signal drops	Loss of live video losses data from image module	Improper soldering, faulty component	PCB sectionally tested	Collected images do not meet expected requirements
		Power to components disrupted	Loss of live video losses data from image module	Improper soldering, faulty component	PCB sectionally tested	Collected images do not meet expected requirements
Image Module/ Software	Smooth image acquisition	Software crash	Live video feed interrupted, data not saved	Unexpected errors, discrepency in software between team and client	Building image module using the same software as client uses	None
Image Module/ Module Housing	Light weight	Housing puts project over alloted weight budget	Behavior of subject is impacted and resulting data	Poor material research, inaccurate modeling	Material research, weighing of individual component and entire project	None
	Heat dissipation	Housing incorporates heat dissipation solution	Causes component shut down, shortens lifetime of components	Inaccurate thermal simulation, poor design, incorrectly calculated thermal output of PCB	Material research, redundant thermal simulations, physical stress test	Thermal shutdown of components during testing

Final Design

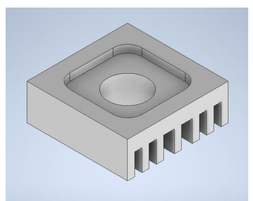




Final PCB design

The **image module PCB** was designed using **fixed regulators** to **reduce part count.**

The **housing** was designed with **1mm.** thick **fins** to improve **heat dissipation** while allowing for **easy manufacturing**.



Final housing design